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Does X(3872) count?

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Counting hadronic states and QCD thermodynamics in a finite box are intimately related. At small temperatures hadronic states are expected to saturate the partition function, so, accepting the Particle Data Group (PDG) table [1] as the reference for hadronic states, all the states listed by the PDG should also be counted as genuine contributions to the QCD partition function and, hence, blindly included in the Hadron Resonance Gas (HRG).

However, Dashen and Kane [2] pointed out the possibility that not all hadron states should be counted on a hadronic scale as they become fluctuations in a mass-spectrum coarse grained sense. Hence, the proliferation of new XYZ states and their inclusion in the PDG poses the natural question whether or not these states have some degree of redundancy in order to build the hadron spectrum [3, 4].
In this work, we analyze if the renowned X(3872), a weakly bound state right below the $D\bar{D}^*$ threshold, should effectively enter a hadronic representation of the QCD partition function. This can be decided by analyzing the $D\bar{D}^*$ scattering phase-shifts in the $J^{PC} = 1^{++}$ channel and their contribution to the level density in the continuum from which the abundance in a hot medium can be determined. For that purpose we use a recent coupled-channels calculation [5] which includes the effect of nearby $D\bar{D}^*$ threshold on the dynamics of the bare $c\bar{c}$ spectrum.

We show that in a purely molecular picture the bound state contribution cancels the continuum providing a vanishing ocupation number density at finite temperature and the X(3872) does not count below the Quark-Gluon Plasma crossover happening at $T \sim 150$MeV. In contrast, for a non vanishing $c\bar{c}$ content the cancellation does not occur due to the onset of the X(3940) which effectively counts as an elementary particle for temperatures above $T \gtrsim 250$MeV. Thus, a blind inclusion of the X(3872) in the Hadron Resonance Gas is not justified.

References

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